COMPAQ
White Paper

July 1998
ECG093/0798

Prepared by ECG Product Marketing Group

Compaq Computer Corporation

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The Benefits of PCI Hot Plug Technology

This white paper summarizes Compaq PCI Hot Plug technology strategy, discusses Compaq's leadership role in the development of the industry standard, and explains the benefits of Compaq's implementation of the PCI Hot Plug standard to help organizations maximize productivity by decreasing server downtime.

Abstract: As an increasing number of companies migrate their business-critical applications to industry-standard servers, the need for redundant features and hot-pluggable components to minimize system downtime is increasing. Each downtime event affects more people at ever-increasing costs. The need has grown beyond "high availability" toward "approaching continuous availability".

Continuous availability requires the elimination not only of unplanned downtime but a reduction of planned downtime as well. Compaq Computer Corporation, the world's leading server provider, has historically taken a leadership role in the development of such industry-standard technologies that are approaching continuous system availability. With the development of PCI Hot Plug technology, an industry standard, Compaq strengthens its role in providing the highest levels of I/O availability solutions for the distributed enterprise.

PCI Hot Plug offers unprecedented server availability by allowing users to replace, upgrade, and add PCI adapters to the PCI local bus without powering down the server. PCI Hot Plug technology benefits also include customer investment protection and efficient manageability and serviceability.

In addition, with the release of the ProLiant 6500 and ProLiant 7000, Compaq made the chassis and electronics design changes required for safe and efficient removal and insertion of PCI adapters without powering down the server. Next-generation PCI Hot Plug solutions are included in Compaq's newest enterprise server, the Pentium II Xeon Model of the ProLiant 7000, released in June 1998.

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The Benefits of PCI Hot Plug Technology
White Paper prepared by ECG Product Marketing Group

Second Edition (July 1998)
Document Number ECG093/0798

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Overview

Customers today need improved availability solutions that minimize or eliminate downtime. Compaq addresses this need by providing PCI Hot Plug technology that allows a PCI adapter to be added, upgraded, or replaced while the bost system is running and while other adapters in the system provide uninterrupted service. PCI Hot Plug technology adds to other high-availability solutions presently available from Compaq such as Recovery Server Options, Redundant Netelligent Network Interface Controllers (NICs), hot-pluggable power supplies, hot-pluggable fans, and bot-pluggable SCSI drives.

Cost of Downtime

Compaq's decision to develop PCI Hot Plug technology is focused on addressing a key customer issue: as computing environments grow more complex, the business costs of unplanned downtime are soaring. The increasing cost of unplanned downtime in business-critical environments, compounded by the time spent tracking the source of network or component failures, is creating a greater need for improved higher availability solutions like PCI Hot Plug. Due to the growing reliance upon computer networks, events resulting in system downtime, whether planned or not, can cripple an organization. Regardless of the cause, the common denominator to all system downtime is a high cost to a customer's business.

A survey of 450 Fortune 1000 companies by Find/SVP[1] found that the average outage across industries lasts four hours and costs $330,000. A typical company experiences nine outages per year, resulting in annual losses of almost $3 million (excluding the cost of lost employee productivity). Actual costs of downtime, however, can vary widely based on individual company size, business type, industry application environment, and type of outage.

Table 1 illustrates the financial impact of system downtime on various industries.[2]

Table 1. Financial Impact of System Downtime

Industry	Business Operation	Industry Cost Range (per hour)	Avg. Cost per Hour of Downtime
Financial	Brokerage Operations	$5.6M to $7.3M	$6.45M
Financial	Credit Cards/Sales Authorization	$2.2M to $3.1M	$2.6M
Media	Pay-per-view	$67K to $233K	$150K
Retail	Home Shopping (TV)	$87K to $140K	$113K
Retail	Home Catalog Sales	$60K to $120K	$90K
Transportation	Airline Reservations	$67K to $112K	$89.5K
Media	Teleticket Sales	$56K to $82K	$69K
Transportation	Package Shipping	$24K to $32K	$28K
Finance	ATM Fees	$12K to $17K	$14.5K

[1] Source: Dataquest, Perspective, Sept, 30, 1996
[2] This table represents only examples of downtime costs. Actual costs may vary. Source: Dataquest, Perspective, Sept. 30, 1996

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As a result of the astronomical costs associated with downtime, the vast majority of companies today require nonstop access to their critical systems. This trend was recently highlighted in a study conducted by the Standish Group International.[3] According to the study, 46 percent of the Fortune 1000 companies require systems availability seven days a week, 24 hours a day (7x24). An additional 39 percent stated that systems were required to be accessible five days a week, eight hours a day. The study also showed that the vast majority of businesses today measure tolerable downtime in mere seconds or minutes. As illustrated in Figure 2, 34 percent of the Fortune 1000 companies can tolerate no more than three seconds of downtime on their business-critical applications. Another 37 percent of these customers require recovery from a failure in less than 3 minutes.

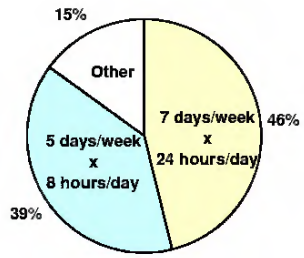

Figure 1. Fortune 1000 Availability Requirements

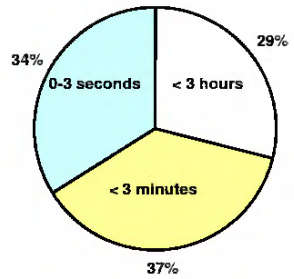

Figure 2. Fortune 1000 Allowable Downtime Requirements

Because the need for improved higher availability solutions that reduce costly downtime is paramount, Compaq's industry-standard PCI Hot Plug technology is specifically designed to minimize the cost of system downtime by increasing server uptime.

[3] Source: The Standish Group International, Inc. Demand Assessment Requirements Tracking Study, 1996

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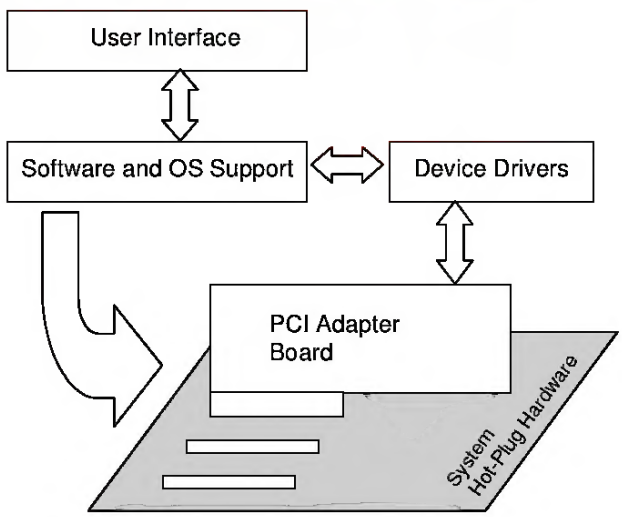
Compaq's PCI Hot Plug Strategy

While advancements have been made to increase server uptime (redundant and hot-pluggable components), one area of availability that has not been adequately addressed is the replacement of pre-failed or failed input/output (I/O) adapters in a running system. Currently, system administrators without PCI Hot Plug technology must power down their servers to repair or expand their network connections or storage online. In enterprise environments, this results in additional costs and lost productivity. PCI Hot Plug technology is designed to address this customer concern. This breakthrough technology offers unprecedented server availability by allowing users to replace, upgrade, and add PCI adapters to the PCI local bus while the system is running.

Taking a very general approach, a fully capable hot-plug system includes hot-plug system hardware (server), hot-plug aware software and operating system (OS) support, hot-plug capable device drivers, and hot-plug aware PCI user interface as shown in Figure 3. The hardware and software work together to ensure that any hot-plug activity occurring on the PCI bus is benign to other devices on the PCI bus. (Note: The vast majority of industry-standard PCI adapters can be made hot-plug aware through the installation of hot-plug device drivers. PCI adapter vendors typically provide these device drivers).

Working in concert, system hardware and software monitor the PCI local bus to identify failed or pre-failed adapters. Upon identification of a faulty or suspect adapter, the system immediately notifies the user with a system alert. Once notified, the user interfaces with the OS to instruct the hardware to isolate and power down the slot (containing the faulty adapter) from all other devices on the PCI bus. The PCI bus can now be accessed and the suspect adapter can be removed. Once a functioning adapter has been installed, the user simply notifies the OS and reactivates power to the isolated slot.[4] The PCI Hot Plug system also protects the system and other adapters from the electrical effects of hot-plug operations.

Figure 3. Generic PCI Hot Plug Technology



[4] Customers using NetWare do not have to interface with the OS to power down the slot; they can utilize the PCI Hot Plug Push Button instead.

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Compaq's PCI Hot Plug Implementation Advantages

Compaq's PCI Hot Plug implementation has multiple benefits including improved availability, an industry-standard approach, customer investment protection, efficient manageability and serviceability, and enhanced and future generation solutions.

Highest Level of I/O Availability

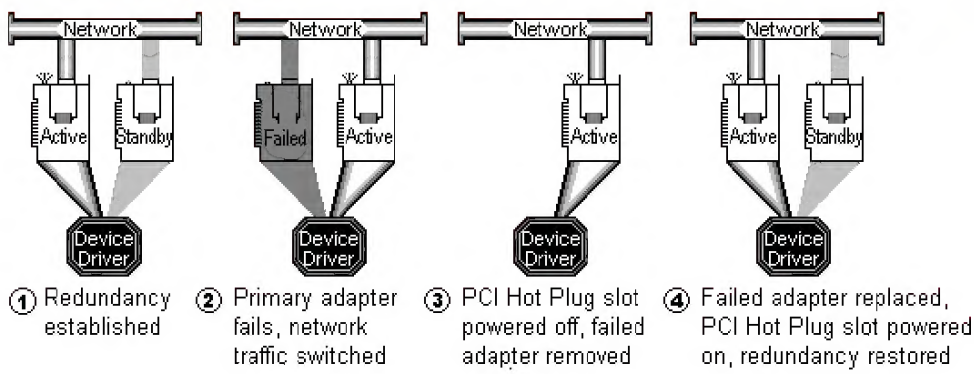
PCI Hot Plug technology represents a significant advance in fault-tolerant systems. PCI Hot Plug technology provides for three major capabilities: hot replacement, hot upgrade, and hot expansion.

- **Hot replacement** is the process of removing a failed or failing PCI adapter and inserting an *identical* adapter into the same slot while the server is operating.
- **Hot upgrade** is the process of upgrading an existing adapter or the adapter's device driver while the server is operating. This allows the customer to reconfigure an adapter without bringing the system down.
- **Hot expansion** is the process of installing an *additional* adapter into a previously empty slot while the server is operating.

Redundant NIC and PCI Hot Plug

To provide an even greater improved availability benefit, PCI Hot Plug technology can be combined with redundant controller configurations, such as Compaq Redundant Netelligent NIC technology. Compaq Redundant Netelligent NIC technology allows two similar NICs to share a single instance of device driver code. One NIC becomes the active network controller, and the other NIC acts as a standby controller. If the active NIC fails, as shown in Figure 4, the network traffic can be switched automatically to the standby NIC. With PCI Hot Plug, the failed NIC can be replaced without shutting down the system. Thus, the end user can have continuous service and the administrator can eliminate both planned and unplanned downtime.

Figure 4. Recovering from a network controller failure using PCI Hot Plug technology and Compaq Redundant Netelligent NICs.



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PCI Hot Plug - an Industry-Standard Approach

Although a pioneer of PCI Hot Plug technology, Compaq chose to develop this new technology as an industry-standard specification rather than a proprietary solution. Not only was Compaq a pioneer in the development of systems hardware, but the company also had extensive experience in systems configuration software and device driver development. Because of its unique position, Compaq gathered the support of major software developers and independent hardware vendors (IHVs) to deliver PCI Hot Plug technology as an open, industry standard.

Since the June 1996 announcement to deliver PCI Hot Plug technology as an open, industry standard, Compaq has worked with key hardware and software partners and the industry-wide PCI standards committee. This effort allows customers to move forward in implementing this technology with greater flexibility. Compaq has taken several steps to ensure broad industry acceptance of the technology, including:

- Standardized PCI Hot Plug technology by initiating and chairing the PCI Special Interest Group (SIG) Hot Plug Workgroup. The workgroup included other industry leaders such as Adaptec, Inc.; Cirrus Logic, Inc.; Digital Equipment Corporation; Hewlett-Packard Company; IBM Corporation; Intel; Microsoft; Novell; Pro-Log Corporation; The Santa Cruz Operation (SCO); and Texas Instruments Incorporated. Efforts of the workgroup allowed quick completion of the PCI Hot Plug Specification - only 14 months from the group's charter- with an official release two months later. For more information on the PCI Hot Plug Specification, visit the PCI SIG website at http://www.pcisig.com.

"Compaq has demonstrated time and time again their ability to take new technology and new standards and integrate them into products very rapidly. The PCI Hot Plug specification is a fantastic example. The capability to remove or insert PCI controller cards into your computer without having to turn the computer off is a very important ingredient in our (Intel's) long-term growth objectives."

-John Miner, Vice-President & General Manager, Enterprise Server Group, Intel Corporation

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- Partnered with OS developers to ensure incorporation of the PCI Hot Plug standard in product releases. Compaq has taken a proactive role in ensuring broad OS support for hot-plug capabilities. Actions to date range from the development of cross-company design teams to the delivery of PCI Hot Plug platforms for testing OSs. Currently, Microsoft, Novell, and SCO support PCI Hot Plug.
- Worked with leading adapter vendors such as 3Com Corporation; Adaptec; Dialogic Corporation; Digi International; Mylex Corporation; QLogic Corporation; American Megatrends, Inc.; Madge Networks; SMC Networks Inc.; and SysKonnect to ensure broad acceptance and rapid implementation of the standard.
- Licensed PCI Hot Plug which will be available to customers who OEM systems and system components from Intel. Intel will incorporate Compaq's implementation of PCI Hot Plug, including the hot-plug controller and related system technologies, in some Intel Pentium II Xeon products and beyond.
- Developed hot-plug aware drivers for Compaq NetFlex controllers, Netelligent controllers, Smart array controllers, and Fast-Wide SCSI-2 controllers.
- Developed the Compaq ProLiant 6500 and ProLiant 7000, announced in August 1997, as the first available server platforms conforming to the PCI Hot Plug Specification and added next-

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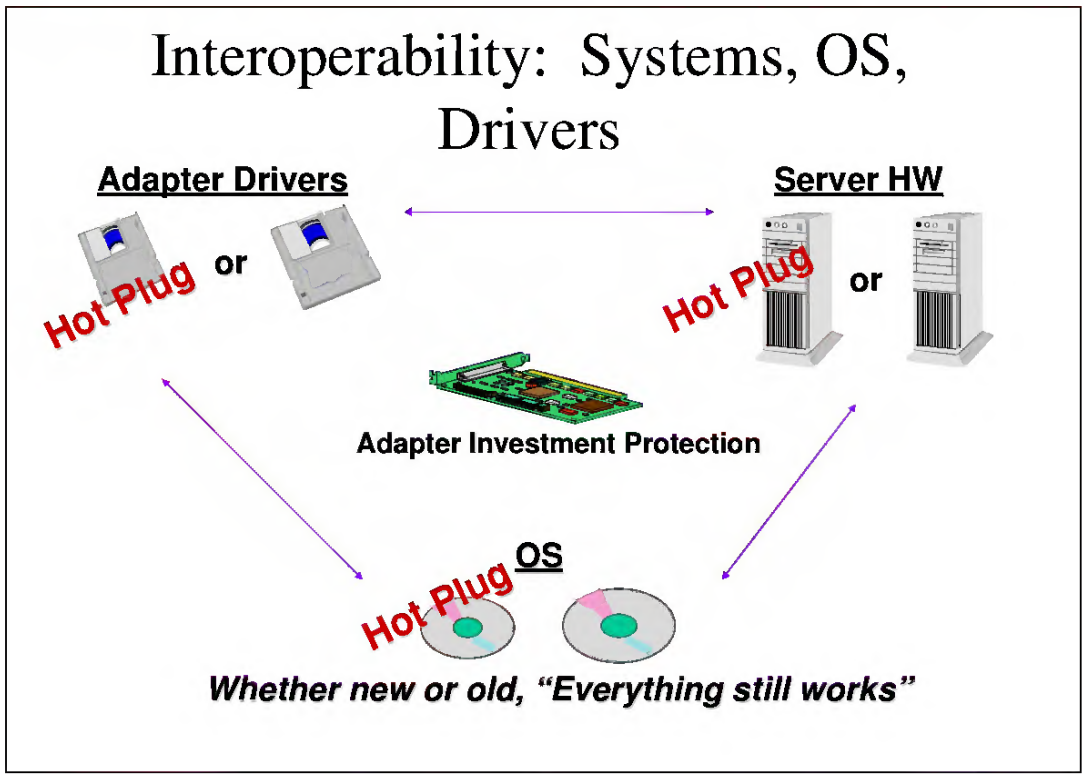
generation PCI Hot Plug features to Pentium II Xeon Models of the ProLiant 7000 announced in June 1998. With these servers, Compaq once again set the standard in improved higher availability and fault-tolerant solutions for the distributed enterprise.

- Provided PCI Hot Plug technology for future certain Alpha-based product lines

Investment Protection

PCI Hot Plug technology is compatible with previous PCI standards; therefore, any new hot-plug system hardware, OSs, or adapters are PCI-compliant and will work with existing PCI-compliant systems. (See Figure 5). The entire system does not need to be overhauled just because certain components are hot-plug capable. Since no hardware changes are required for the vast majority of the installed base of PCI adapters, customer investment protection is assured through backward compatibility.

Figure 5. Due to the backward compatibility of the standard, PCI Hot Plug technology protects the installed base of over 100 million PCI adapters in use today.



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Efficient Manageability and Serviceability

PCI Hot Plug is fully supported by Compaq's industry-leading systems integration and management tools, Compaq SmartStart and Compaq Insight Manager. For example, SmartStart CDs contain the device drivers necessary to make Compaq adapters fully hot-plug capable. In addition, Insight Manager identifies which PCI slots are hot pluggable and alerts system administrators when adapters malfunction. All PCI Hot Plug alerts and actions can also be posted on Compaq's Integrated Management Display (an LCD display housed on the front of the server that provides text-based service and diagnostic information) or accessed through Compaq's Remote Insight Board (a remote server management tool).

Compaq systems have also been designed to increase system uptime by reducing the time associated with component replacement. The once laborious task of accessing PCI adapters has been simplified through the use of a tool-free access door. (See Figure 6). In addition, light-emitting diodes (LEDs) have been installed above every PCI Hot Plug slot for easy identification of failed components. The LEDs can be viewed from above the system when the access door is open or from behind the machine (ensuring clear visibility from all vantage points). Normally functioning adapters are indicated by green LEDs and failed or suspect adapters are indicated by amber LEDs.

Figure 6. Tool-free access door enables quick replacement of hot-plug aware PCI adapters.

Enhanced Solutions

Compaq has worked within PCI Hot Plug specifications to provide enhanced solutions such as the PCI Hot Plug Push Button and the Extended SCSI PCI Bus Connector. The Compaq ProLiant 7000 now offers a new PCI Hot Plug Push Button for all 9 PCI Hot Plug slots. The button is pressed to signal the software to initiate a power state change. This easy-to-use push button provides slot power control directly at the server, independent of PCI Hot Plug software utilities to simplify and speed maintenance and installation of PCI cards. The new button is more convenient and simpler, allowing customers to remove the adapter without going through the user

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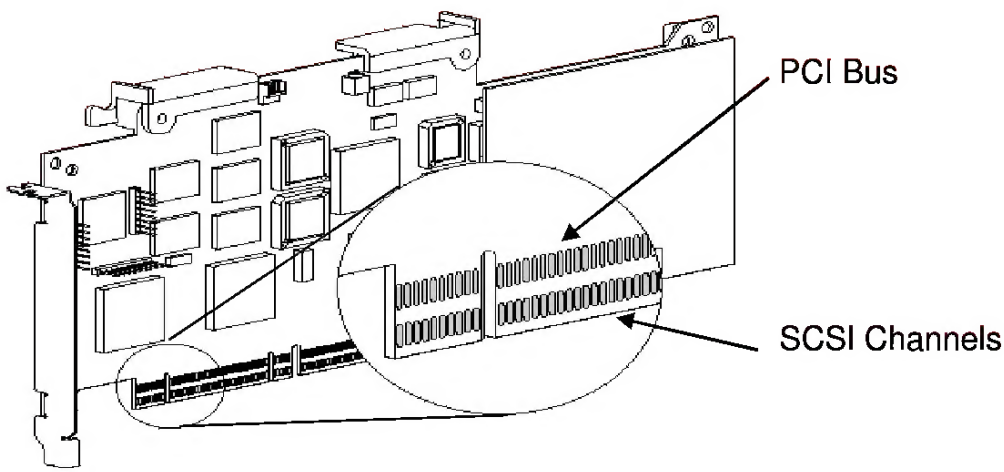
console. The ProLiant 7000 also offers PCI 32-bit and 64-bit PCI slots, and is Microsoft Server 98 compliant.

Compaq also has provided future generation solutions for PCI Hot Plug technology with the new Extended SCSI PCI Bus Connector, a cableless design. SCSI channels are distributed through the Extended SCSI PCI Bus Connector resulting in no SCSI cables attached to the array controller adapter as shown in Figure 7. This design facilitates service and eliminates SCSI cabling, further simplifying PCI Hot Plug operation.

Figure 7. PCI Extended SCSI Bus Connector routes SCSI buses through I/O adapter to drive cages.



Conclusion

With the introduction of PCI Hot Plug technology, Compaq Computer Corporation once again sets the standard in improved higher availability and fault-tolerant solutions for the distributed enterprise. PCI Hot Plug offers unprecedented server availability by allowing users to replace, upgrade, and add PCI adapters to the PCI local bus without powering down the server. In addition, PCI Hot Plug is backward compatible with the vast majority of PCI adapters in existence today. As a pioneer of this breakthrough technology, Compaq chose to deliver PCI Hot Plug as an industry-standard specification. This decision provides several benefits to customers and has been critical to the overwhelming support received from industry-leading partners. Compaq is committed to providing customers with a comprehensive range of improved higher availability and fault-tolerant solutions and will continue to take a leadership role in future developments of the PCI Hot Plug standard and other emerging technologies.

For More Information

For further information on PCI Hot Plug technology, please visit Compaq's website at http://www.compaq.com. Papers include:

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"PCI Hot Plug Technology"

http://www.compaq.com/support/techpubs/whitepapers/ecg0800698.html

"PCI Hot Plug Technology with Novell Architecture"

http://www.compaq.com/support/techpubs/whitepapers/ecg0810698.html

"PCI Hot Plug Technology with SCO Architecture"

http://www.compaq.com/support/techpubs/whitepapers/ecg0820698.html

"Deploying PCI Hot Plug on Compaq Servers in a Microsoft Windows NT Environment"

http://www.compaq.com/support/techpubs/whitepapers/064a0797.html

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